the hacker's guide to the beavis board

beavis audio research
Revision 1

Hi there!

Thanks for purchasing the beavis board. The kit is designed to make it easy to get into Stompbox hackery, or if you are already into hackery, a great prototyping tool to add to your arsenal. Here are some of the key points of the beavis board:

- Dual breadboards: for plugging in various bits
- Breadboard jumpers: for connecting things together
- I/O Break-out box: putting all the input/output stuff in a reliable, reusable box
- Terminal strips: for connecting other parts that don't fit on a breadboard
- Parts: lots of passive and active components for building a huge array of stompbox-related circuits without the hassle of trying to source parts yourself
- Hacker's Guide: You're reading it!

Getting Started

This guide is designed to get you up and running as quickly as possible. There are some basic prerequisite things to learn—if you are already an old-hand, you can just skim those parts. From there, we'll move on to some circuitry fundamentals and talk about schematics and how they map to the physical model of the beavis board. We'll finish off the Hacker's Guide with some projects. Here's what we'll cover:

- Setting up and using your beavis board
- All about Breadboards
- The Parts Bag
- Quick Start: Build something now!
- Troubleshooting

Get the Projects

Project files are located here: www.beavisaudio.com/bboard/projects

Check That Website

Be sure to check the beavisaudio.com website often. I've always got new stuff to share. Main website: www.beavisaudio.com Beavis board: www.beavisaudio.com/bboard

Table of Contents

the beavis board: why?

I designed the beavis board to make it easy for you to learn about the dark magic arts of stompbox circuitry. To do that, I looked at all the problems I had seen before in my own circuit-building attempts, the litany of questions on the DIY forums, and the loads of email questions I get at Beavis World Headquarters. Most of the problems are centered around a few key areas:

Problem 1: Learning Soldering Sucks!

Yes it does. That's not to say it isn't an essential skill that we all should have, but it shouldn't stand between you and initial hacker success. Soldering is a bit of an art, and the more you do it the better you'll get. But it is a sometimes steep learning curve. And even if you know how to solder, there are lots of times when you just want to prototype and tweak things without dealing with soldering.

The beavis board solution: No soldering required! (But you should still learn to solder…)

Problem 2: Breadboards can be a hassle!

Yes they can. Breadboards make it really easy to stick components into and prototype and experiment. But they are really ungainly to work with. You have to stick a jack somewhere into the board for your guitar. And another for your amp. Then you need to dangle on a battery clip. When you get the whole mess working, you'll move your guitar and the input jack falls off the board. Plus, your circuit ends up as a breadboard with a whole bunch of stuff hanging off it—what happens when you want to move your creation over to your pedal board or amp to see how it sounds in your rig? Arghh, that's a nightmare. Finally, unless you wire in a 3PDT switch, there is no bypass for your creation so you can't readily experiment with levels, interactions with other stompboxes, and all the other things that you would do with a normal pedal.

The beavis board solution: the integrated I/O breakout box gives you a rock-solid metal enclosure with input and output jacks, a power jack, 3PDT true-bypass switching, a voltage sag knob and a switch, all ready to go.

Problem 3: Parts Sourcing Blows!

Yes it does. It took me two years to understand enough about parts to order the right thing. I have boxes full of strange surface-mount (SMD) capacitors and pots with 12″ shafts, and all sorts of other unusable bits. This is because there are literally millions of parts in a huge bewildering array of configurations and sizes. I can't tell you how many emails I get from people who get excited about a project, order parts, and end up with the wrong stuff. Of course, we get exactly what we ordered—we just don't always do a good job of ordering what we really wanted.

And part value is another hassle: how do I know what capacitors to have on hand for various projects? What is a good set of transistors for general stompbox usage?

The beavis board solution: A great collection of resistors, capacitors, transistors, diodes, ICs and other assorted parts that gives you the bits you need to build a lot of cool circuits.

Problem 4: Schematics: WTF?!?!

Yes, WTF indeed. A lot of times, folks want to try a project and get a schematic only to be confounded by what to do with that schematic. Do I put that on a breadboard? If so, how? Or do I use a veroboard layout? How do I do that? What about etching boards? All I really want to do is build something that works!

The beavis board solution: a hacker's guide that shows you both the schematic and how to lay it out easily and quickly on the breadboard. You'll be surprised how much schematics can make sense as you work through the projects and see both the schematic (abstract) representation and the breadboard layout (physical) representation side-by-side.

But What about Making Actual Pedals?

So that's all cool and stuff, but what if you want to make actual pedals that you can put on your pedalboard? Well, building a permanent stompbox is not the point of the beavis board. It is about learning how to build just about anything you want circuit-wise. It's about learning how the different components affect the sound, and how you can mod values and parts to make something that is distinctly yours.

That process is not mutually exclusive with building stompboxes. Rather, it is part of the greater body of knowledge, experience and just plain fun that goes in the art.

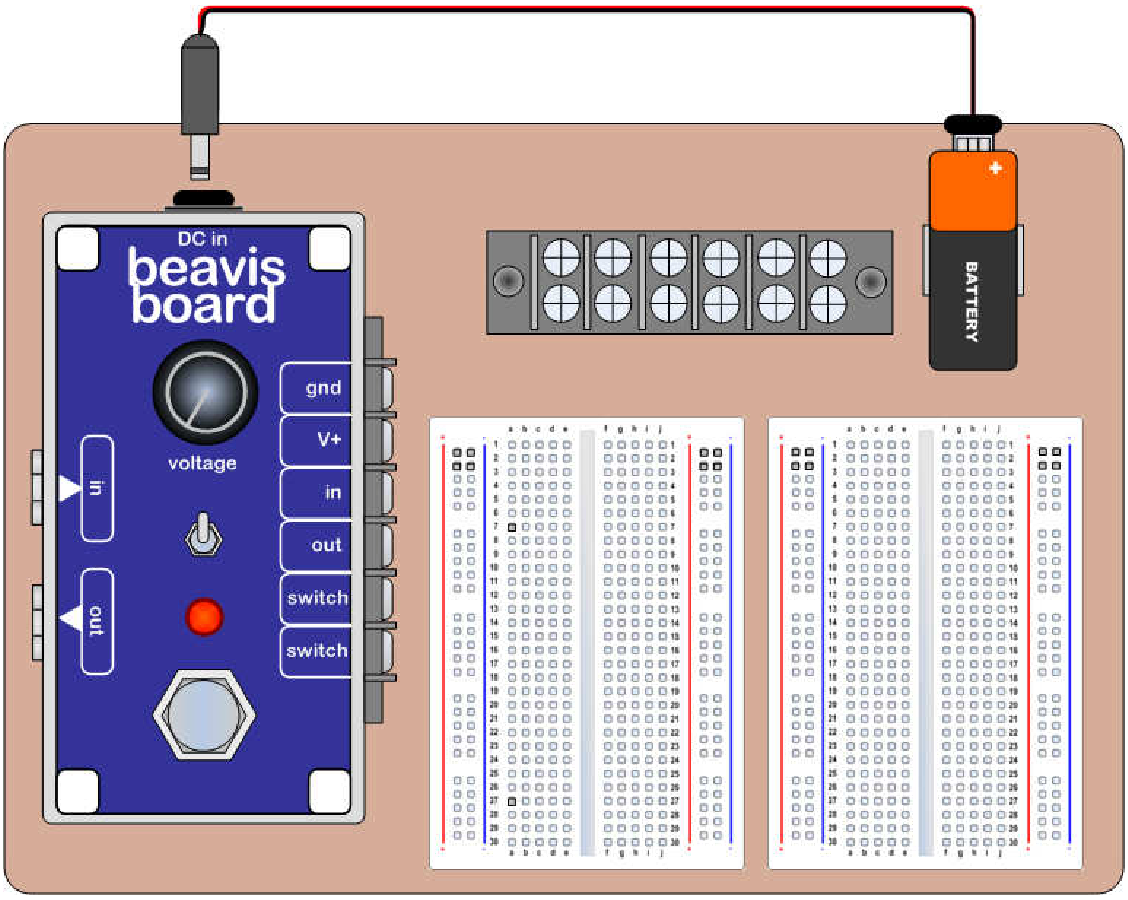
Think of the beavis board as your design studio. Use it to learn and hack and tweak and mod. Listen to the results, stick it on your pedalboard and see how your projects interact with other pedals and your amp and guitar. It is your palette, and you are the big studly artist.

And when the time comes to build your creation into an actual pedal, there are lots of ways to accomplish that, like starting with a kit that is close to your circuit. Or learning about perfboard and veroboard as building options. You can even get prototype PCB boards that closely match the breadboard, making it easier than ever to transform your creations into road-worthy sonic masterpieces.

But for now, let's get back to the beavis board, and all that crap about palettes and artistry.

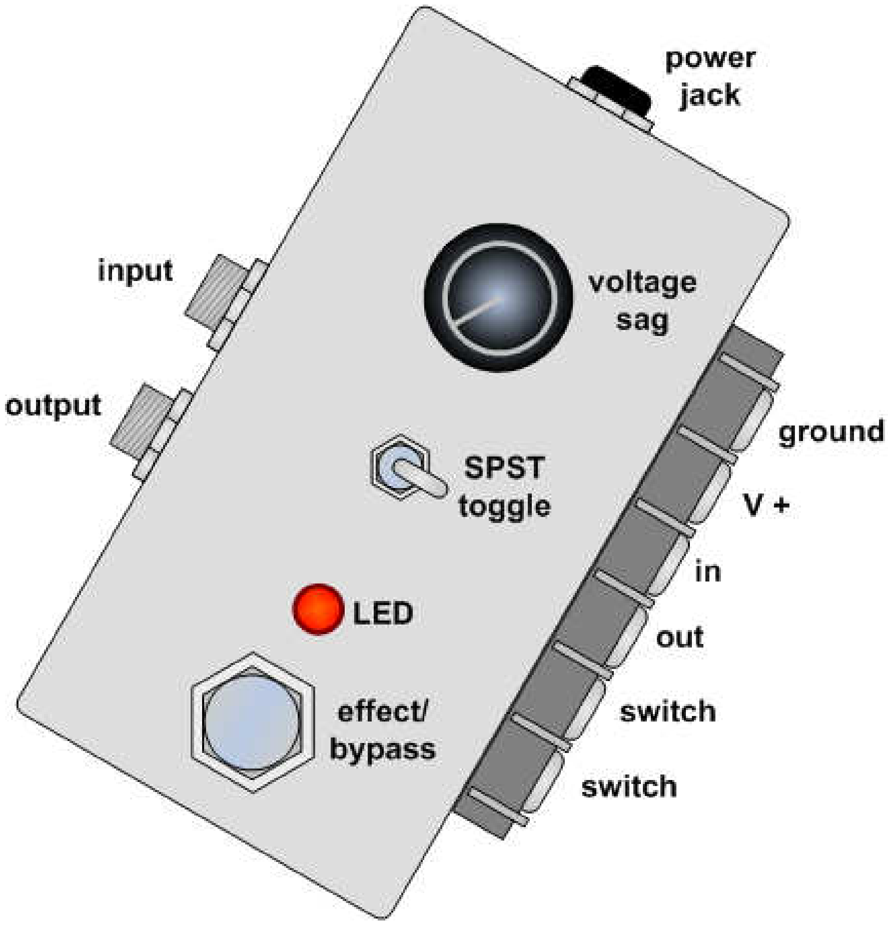
The beavis board in detail

Ok, so by now you have a vague idea of what you can do. How about some specifics? First, let's look at the actual beavis board in a bit more detail. You have a metal box with knobs and things, a breadboard, a battery clip, and a terminal strip, all securely attached to a Hunk o' Wood™.



The I/O breakout box

First off, I/O stands for input/out. It is a cool engineering term and I love to use it. So the metal box with knobs and things is the breakout box. What this does is give you a reliable way to interface your breadboard design with the physical things you'll need: mainly your guitar cord, the cord to your amp, a power supply, and a true-bypass switch.



Here's a breakdown of each of the parts:

- **Input and Output jacks:** Plug your guitar into the input jack. Plug your amp (or another pedal) into the output jack. The arrangement is exactly the same as any stompbox pedal you have used.

Important Jack Note

Note that the input jack is not a "turn off" jack like on an actual pedal. In other words, you are not disconnecting the battery/power source on the beavis board when you remove a plug from the input jack. I built it this way because you want power flowing to the breadboard for testing and may not necessarily want to plug your guitar in all the time.

To disconnect power from the beavis board, unplug the power cord going into the I/O Breakout Box power jack.

- **The Power Plug:** This is where you plug in power. Your beavis board kit includes a little adaptor that connects a standard 9 volt battery to a standard 2.1mm Boss-style power connector. Attach the battery clip to the battery and plug the plug end into the power jack. You can also use a standard Boss-style AC/DC adaptor to power your beavis board.
- **The Stompswitch:** This is a standard 3PDT switch wired for true bypass just as in any other true bypass stompbox. Press the switch once, the LED indicator comes on, and the signal flows from the input jack to the breadboard and back out to the output jack. Press it again, the LED indicator goes out, and the signal goes directly from the input jack to the output jack, bypassing the breadboard.
- **The Voltage Sag Knob:** This knob lowers (or 'sags') the input voltage going from the power orifice to the breadboard. Turn it fully clockwise to get full voltage. Turn it counter-clockwise to reduce voltage. For most projects, you'll keep the knob full clockwise so that the breadboard receives full power. For others, you can experiment with 'sagging' the voltage to hear great grunginess and glitchy type sounds. (Especially fun with the fuzz circuits).
- **The Toggle Switch:** This switch makes it easy to incorporate a Single Pole Single Throw (SPST) switch into various circuits you build. More about that later. For now, it doesn't matter which position the switch is in.
- **The Terminal Strip:** This is where you connect wires from the I/O Breakout Box to the breadboard. The terminal strip is an ingeniously simple device: use a screwdriver to loosen a screw. Insert a piece of stripped wire under the screw head, and tighten the screw. Genius. We'll talk more about the terminal strip in the next section.

The Main Terminal Strip

As with the terminal strip on the I/O Breakout Box, this one sits above the breadboard. It is useful when you need to connect things that don't have wires that fit conveniently into the breadboard. For example, let's say you want to add a speaker to a specific project. Most speaker cable is too thick to fit in a breadboard hole. So you attach the thick-ish speaker wire to one side of a terminal strip segment, and a breadboard jumper wire to the other. Pretty simple!

Battery Holder

There is a metal battery holder attached to the beavis board just above the terminal strip. Plug your 9 volt battery into the battery snap and slide it into the holder.

Other Important Stuff

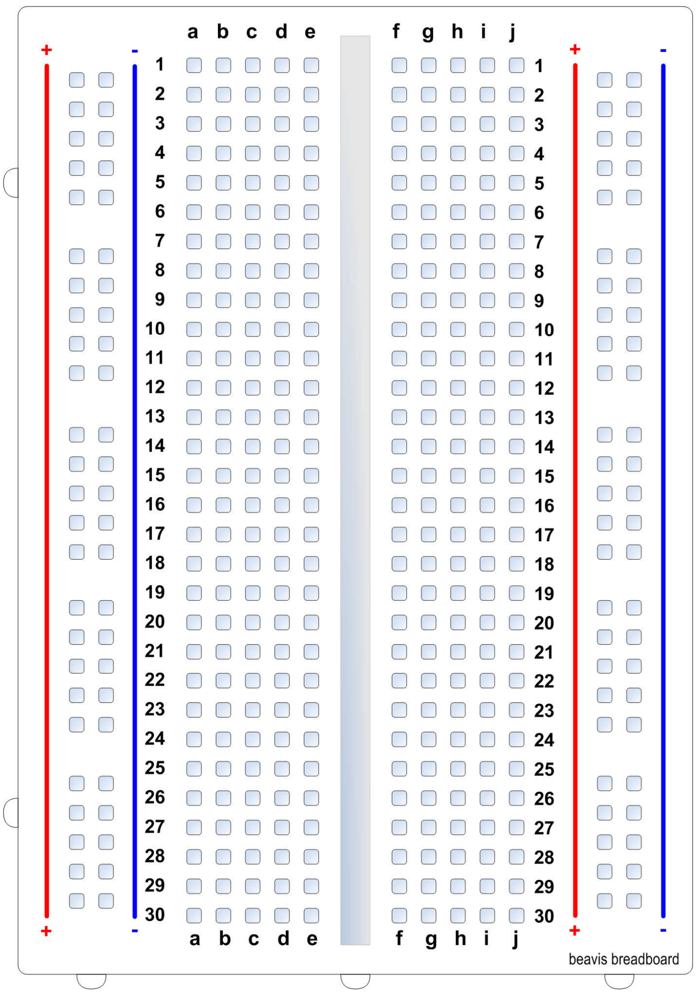
Beyond the beavis board itself, there are a couple of other things in the box:

- **Breadboard Jumper Wires:** There is a box of jumper wires. They are solid core wires with insulation of various colors and come in various lengths. Note that the colors don't really matter in that they don't match up with any "standard" for electronics, so as you are working with projects, you'll find that you choose jumpers by length, not by color.
- **Battery:** A 9 volt battery to power the thing.
- **Battery Plug thing:** A 9 volt battery snap wired to a 2.1mm plug. Use this to power the beavis board.
- **Lots of Parts in Bags:** Enough to start your own pedal empire! We'll cover the parts in detail later in this guide.

All About Breadboards

Breadboards are probably the most common prototyping platform used in electronics. Probably because they make the process so easy. Breadboards come in a large array of sizes and configurations, but all follow the same basic principle: a bunch of pattern-connected holes that you stick components and wires into. What makes the breadboard truly useful is how these patterns are connected inside the breadboard.

The beavis board uses two medium-size breadboard containing 400 holes. There are 300 holes in the main area, and 50 holes that comprise the power busses on each side of the board. Here’s what it looks like. The main are consists of a bunch of pads of 5, two sets on each side of the divider running down the middle. These are conveniently identified using a grid of numbers and letters, just like when you used to play Battleships. On the left side is a set of power bus connections. The + side is next to the red line and the negative side is next to the blue line. The same power bus arrangement is duplicated on the right hand side of the board.



Why Two Breadboards?

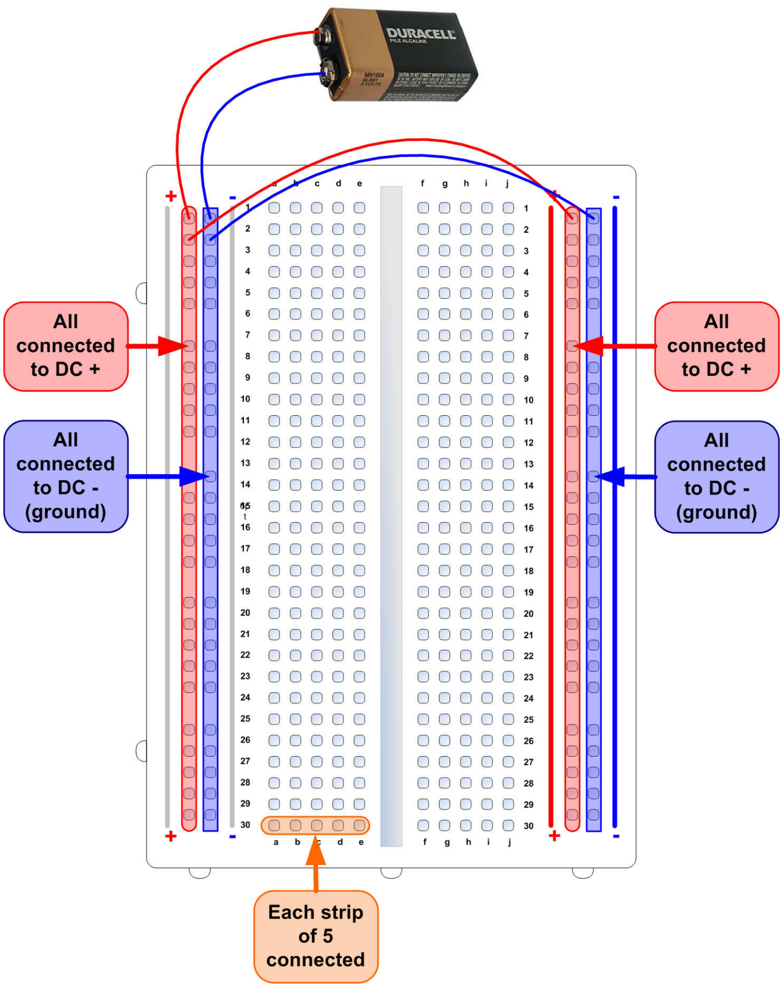
I included two breadboards to make it easier to:

- Split larger projects into more workable areas, or
- So you can keep one circuit in place while you build another, which is especially useful when you want to hear how one circuit sounds when fed by another.

The two breadboards are identical in function.

Connections underneath

Underneath the breadboard are a series of metal strips that connect the holes in an entirely useful way.



On the outer left and right of the board are power distribution areas. The red areas show the positive (+) connection and the blue areas show the negative (-) or ground, connections. You can see from this diagram that you wire the power source (for example a 9 volt battery) running two wires from the positive side to the red busses and the negative side to the blue busses. In this arrangement, you can easily access positive voltage and ground from anywhere in the main area.

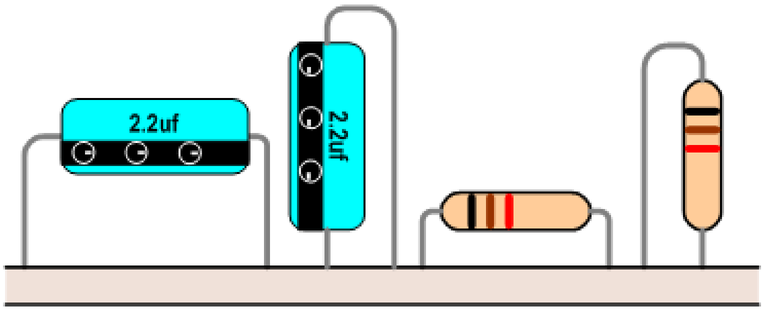
In the main area, there are a bunch of strips of five. Each of these strips of five is a single connection. So A1 is connected to B1, C1, D1, and E1. Similarly, F30 is connected to G30, H30, I30, and J30. This simple arrangement makes it quite easy to quickly and accurately lay out circuits.

To connect points, you use the breadboard jumpers which are lengths of insulated solid core wire with stripped ends.

Placing components

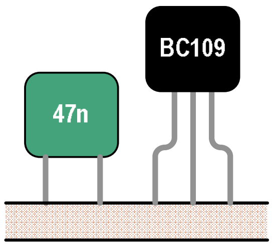
Most of the components in your kit have wire leads. These get inserted into the holes in the breadboard at various clever points. You then use the jumper wires to finish the connections. Go ahead and grab a few parts and some jumpers. Stick them in the board—don't worry about making anything yet, just get a feel for the zen-like experience that is breadboarding.

For "axial" components where the leads come out of the ends, like your resistors, you can place them horizontally or vertically. Horizontal is usually the best because you can easily see the value. Vertical is good for when you want a more compact layout.



Horizontal and Vertical Orientations

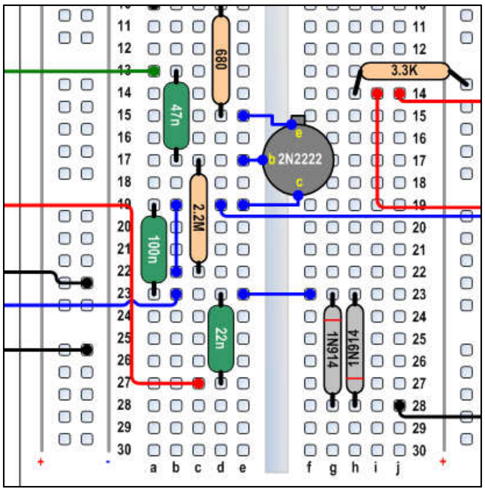
Radial components are where the leads come out of the same side of the component, like transistors and radial capacitors. As above, use the orientation that works best for you. For transistors, you'll want to bend the leads just a little as shown below to make for a wider spacing on the breadboard to give yourself a little more design room:



A radial capacitor and a transistor

How We'll Show the Components

As you build the projects in this guide, you'll see layouts like this:

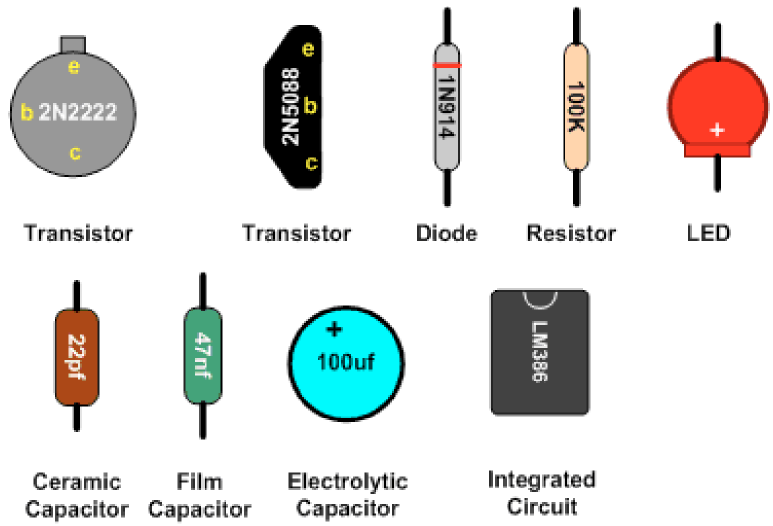


Important Note About Wire Colors

The wire color shown in the diagrams throughout this guide are not supposed to necessarily match the colors of the wires in your jumper wire kit. I have used wire color in the illustrations for purposes of clarity.

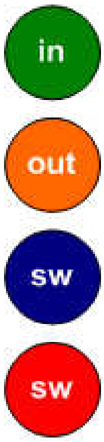
When you build stuff, use the wires that have the closest length to what you need, regardless of color.

Here's a list of the components and how they are shown:



Note the polarity markers on the diode (a red band) and the electrolytic capacitor (+ sign). Also note that the pin out is shown on the transistor symbols, and a notch indicates pin 1 on the integrated circuit. We'll talk about all those things in detail when we talk about the parts stash. For now, just remember to orient the components on the breadboard as shown by these symbols.

The connection points to the i/o breakout box are signified with colored circles:



Wear, Tear, and the Inevitable Demise of your Breadboard

As the sage R.G. Keen said: breadboards are like underwear, they need to be changed often. Through the process of jamming wires and leads into the board and yanking them back out over and over again, the metal conductors wear down. Over time, this will result in holes that no longer conduct, or are intermittent. This can hugely frustrating as you try and figure out why your circuit doesn't work, only to realize after much gnashing of teeth that you breadboard is farkled.

The good news is that breadboards are fairly inexpensive. If yours shows signs of wearing down or getting flaky, google 'breadboards' and you'll find a lot of good resources for breadboards of all sizes and configurations. Try and find one that is roughly the same size as the one on your beavis board so it still fits on the Hunk o' Wood ™.

Jumper wires will also wear out and break over time. The stripped ends tend to break off. If that happens, just use your wire strippers to make a new end. If a broken end gets stuck in a breadboard hole, use a small screwdriver or toothpick to try and coerce it out of the hole. You can get more jumpers online or even at most Radio Shack stores.

Breadboard and Noise

Breadboards are going to lead to a noiser circuit than if you have it enclosed on a stompbox. This is one of the inevitable trade-off's for the breadboard's ease of use and convenience. For most of the projects you build, this won't be a problem. But for high-gain circuits (the ones that amplify the signal many many times) you will hear noise and hiss. To combat this, try to keep your breadboard layout as compact as possible, and avoid using long wires wherever possible. The good news is that the shielded i/o breakout box helps a lot with the noise issue.

Setting Up: Connecting the I/O Breakout Box to the Breadboard

In this section, you'll spend a few minutes getting your beavis board ready to use. This involves setting up the power. First, we'll look at working with terminal strips, then we'll wire the board up for power.

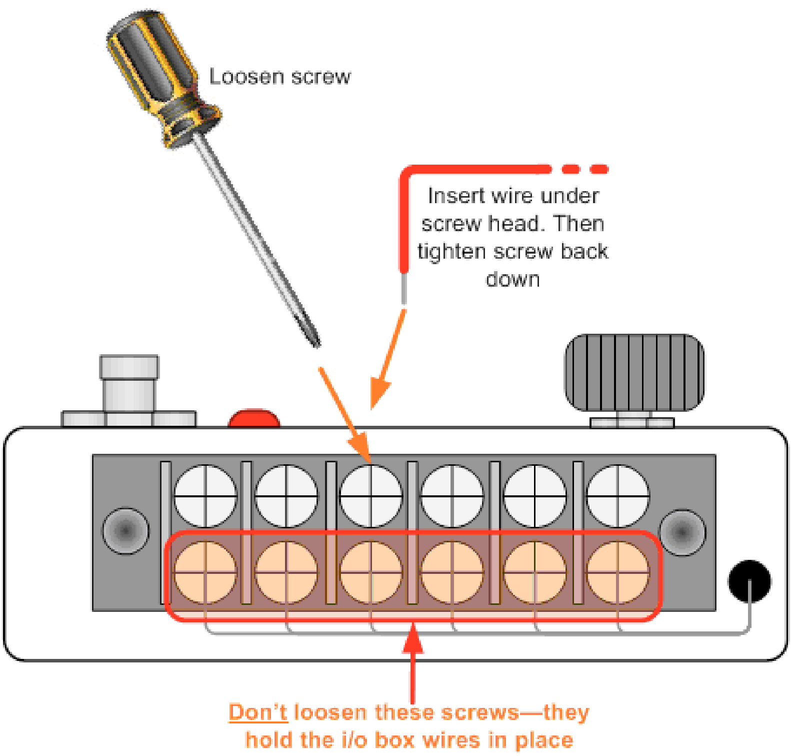
Working with Terminal Strips

On the side of the i/o breakout box is a terminal strip. Each lug screw on the terminal strip serves a specific function, as labeled on the top of the I/O breakout box.

Your kit comes with a bag of red jumpers, you can use these to make your i/o box-> breadboard connections.

To attach wires to the terminal strip:

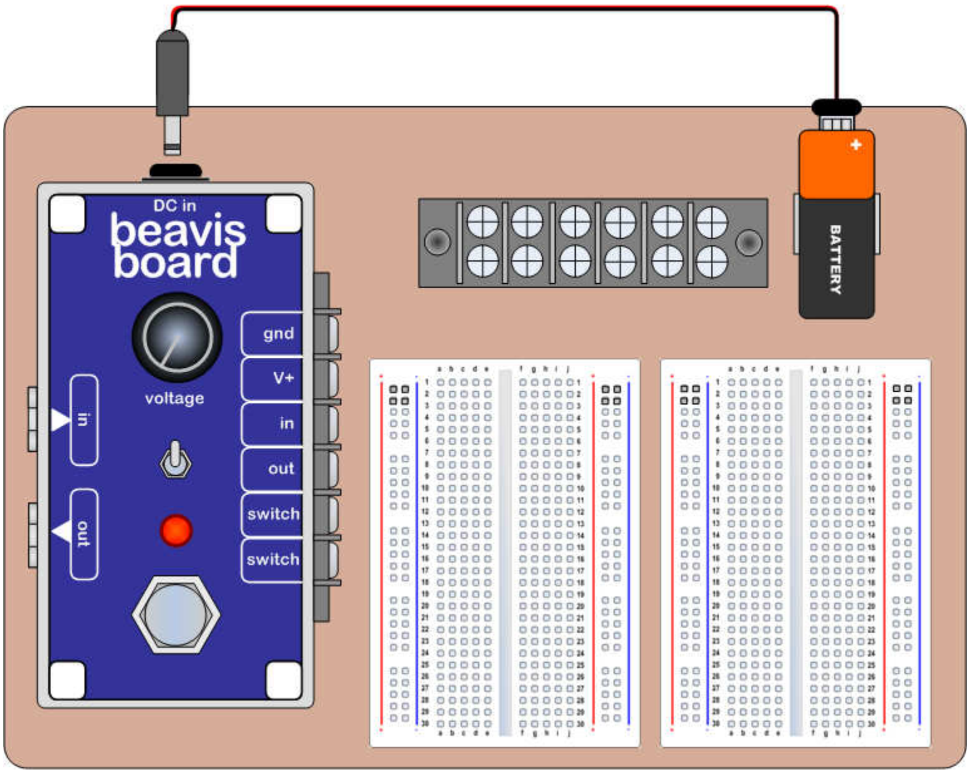
1. Loosen the screw (Top row only! The bottom row is for the I/O box's internal wiring) with a slotted-head screwdriver.
2. Insert the stripped end of one of you breadboard jumper wires under the screw head
3. While holding the wire in place, tighten down the screw.
4. Double-check your connection—you want a good metal-to-metal contact.



Connecting a Power Source

You kit ships with a 9 volt battery. You can use this to power your projects, or you can use a 9v adaptor. The i/o breakout box is wired just like every other standard pedal: 2.1mm Boss-style plug with a negative tip. So you can use a standard BOSS-type adaptor. To hook up battery power:

1. Connect the battery snap to the battery. Insert the battery into the battery holder clip. (Over time, the battery clip may get a little stretch out, like sleeve of wizard. If this is the case, simple remove the battery and gently press the metal sides towards each other.)
2. Connect the plug end of the battery cable into the i/o breakout box.
3. To test your connections, plug a cable into the i/o breakout box input jack and press the effect/bypass stompswitch. The LED should come on.

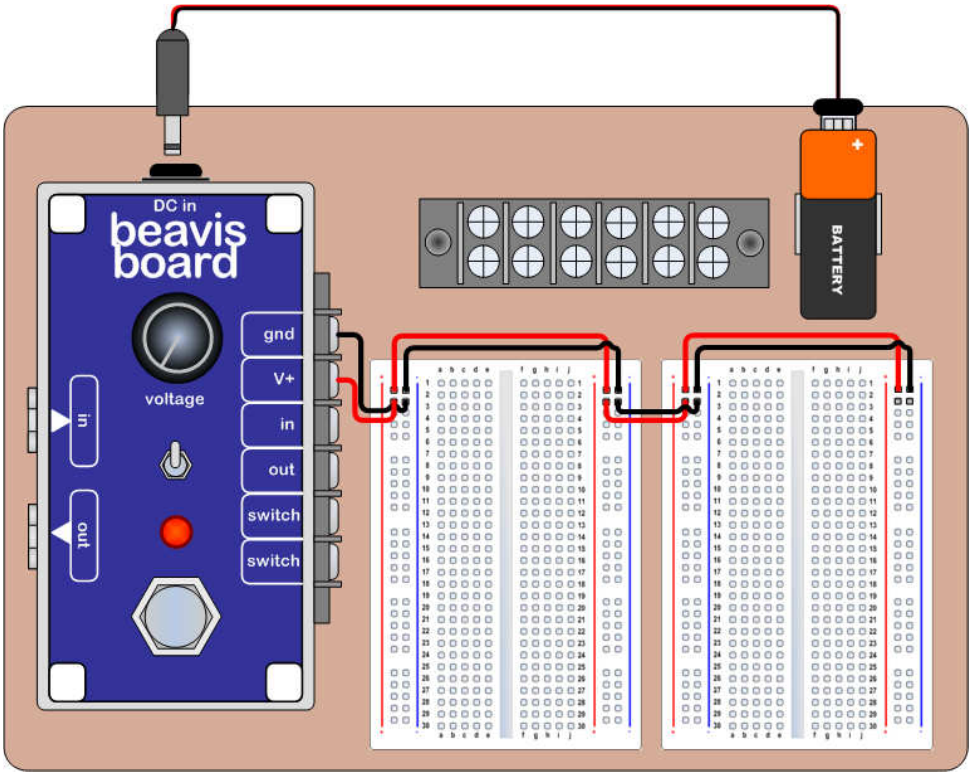


Connecting Power to the Breadboards

The next step in preparing your beavis board is to route power to the breadboards. Using the steps outline earlier (Working with Terminal Strips), run on of the breadboard jumper wires from the i/o breakout box ground to the first ground, or negative, bus on the breadboard.

Then run a wire from V+ on the i/o board to the first positive bus on the breadboard. You now have power running to the left bus on the first breadboard.

Follow the wiring shown below to add power to the remaining three the power bus strips.

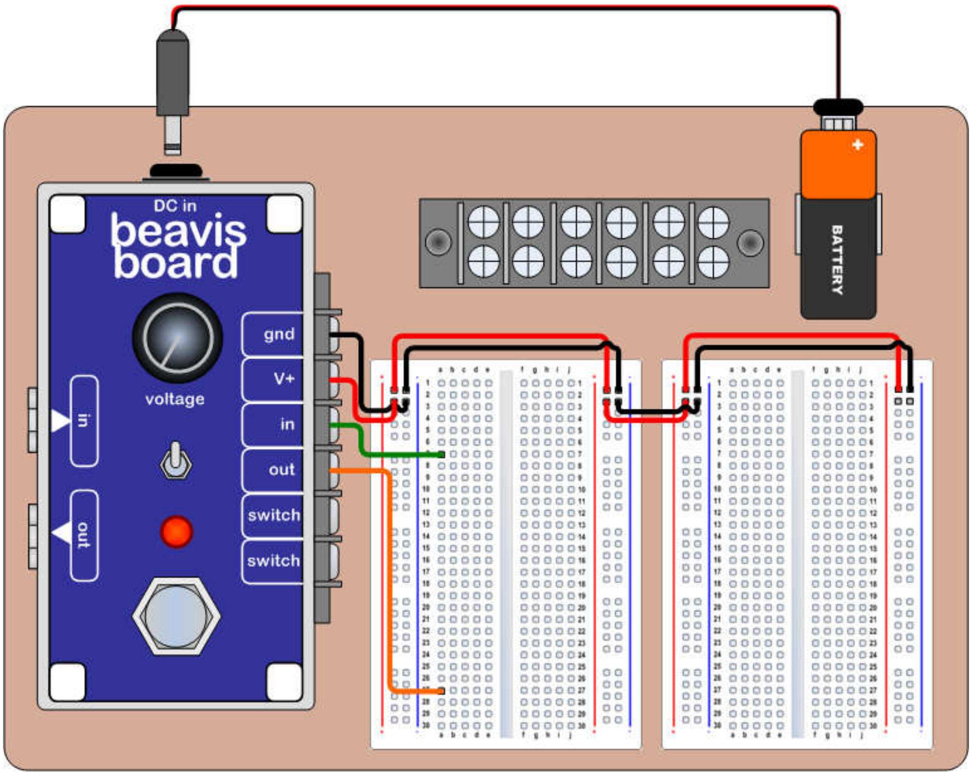


For the most part, this wiring will always be in place. You'll never really need to rewire the power layout shown above. Because it will be semi-permanent, take some time to make the wires neat so they don't get in your way as you work on projects. I like to use needle nose pliers to make the bends nice and perfect, and trim the wires to be just the right length.

Connecting the Input and Output Wires

The last wiring task is to connect your input and output wires. These connect the input jack on the i/o breakout box to the input of your circuit, and similarly with the output. Attach one wire to the input jack, and another to the output.

Where you insert these two wires on the breadboard will depend on the specific circuit you are building, but in general the input will be towards the top of the board and the output will be towards the bottom.



Testing

To test the connections, insert the battery into the battery holder and plug the connector into the i/o breakout box. As a quick test, press the stompswitch: the LED should go toggle between on and off with each press. To ensure that each of the power busses on the breadboards are getting power, get your digital multimeter, turn it on, and set it to the DC range that is closest to 9 volts. Use the test probes to check each of the locations where there should be power: put the black lead on the negative bus and the red lead on the positive bus. Check for correct power (it should read somewhere around 9 volts) on each of the four power busses.

All Done

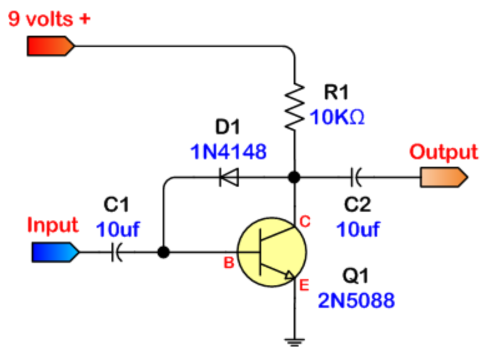
Congratulations, you mad scientist! Your beavis board is ready to go.

Enough with Prose! I Want to Build Something!

I hear ya! There is a lot of important information still to come in this hacker's guide, but I'm sure you want to get some instant gratification.

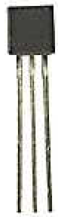
So here you go: a great fuzz circuit based in hemmo/christian's ultra simple bazz fuss circuit. This one is very easy, has minimal parts, and sounds great.

First, the schematic.

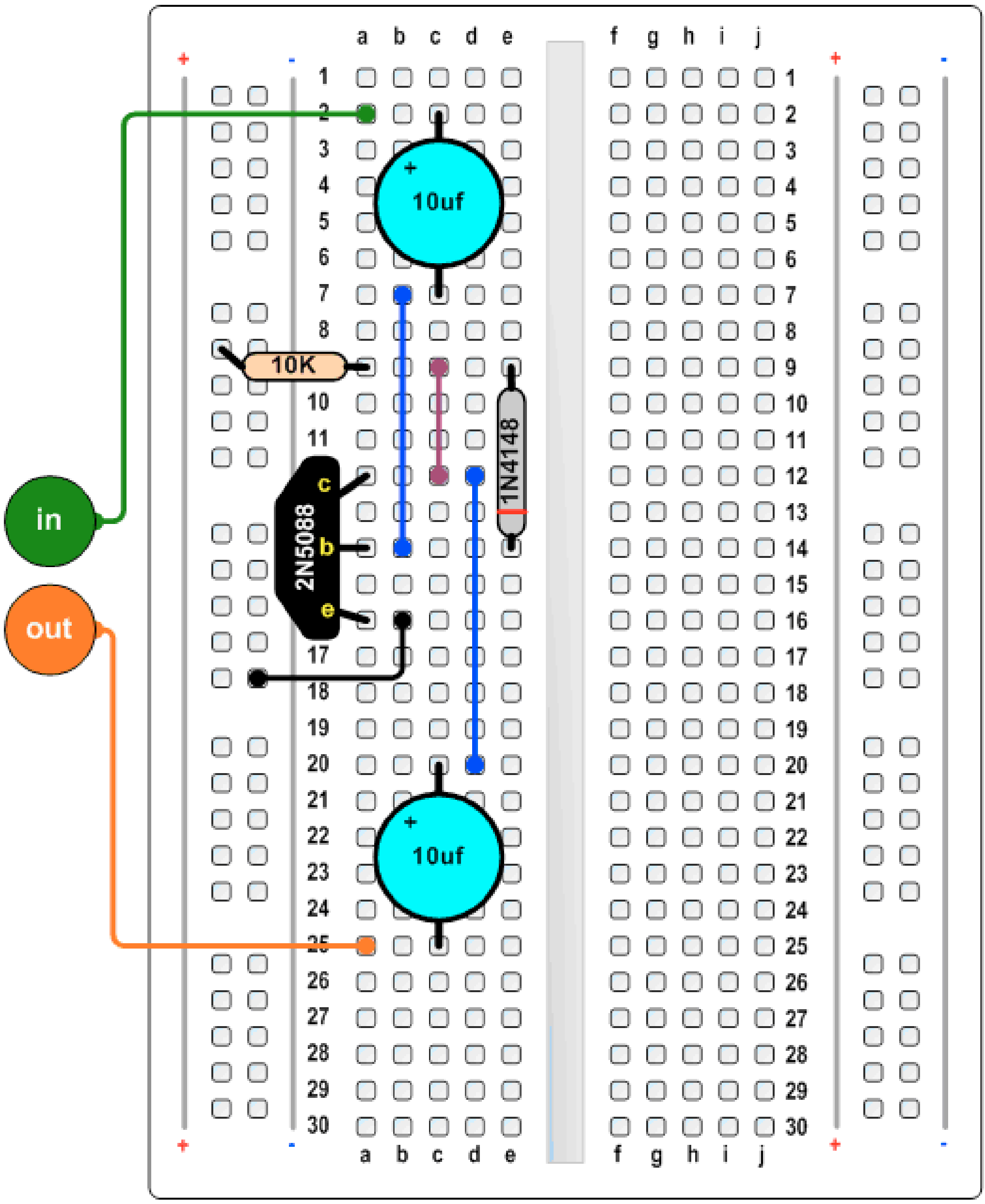


Wait! A schematic? What if you can't read a schematic? No worries, just take a quick glance at it as you are sticking parts in the breadboard. As I mentioned earlier, seeing how a schematic lays out on a breadboard is an incredible learning tool.

Now let's actually build it. Gather together the following components:

Part # on Schematic	Value	What it looks like	
C1	10 uf electrolytic capacitor	It has 10uf written somewhere on it.	
D1	1N4148 diode	Clear glass diode, reddish with a black band.	
Q1	2N5088 Transistor	Black plastic body, 3 legs, says "2N5088" somewhere on it	
R1	10K resistor	A resistor with the following color bands: brown black orange	
C2	10 uf electrolytic capacitor	Just like C1	

Insert the parts as shown here.



Ready to Test

1. Plug your power source into the i/o breakout box.
2. Turn the voltage sag on the i/o breakout box all the way clockwise.
3. Plug your guitar into the input jack in the i/o breakout box.
4. Plug your amp into the output jack in the i/o breakout box.

Did it work? Great! Did it not work? Check out the troubleshooting section later in this guide.

The Parts Stash

One of the best parts of the beavis board kit is the collection of parts. Why is this good? Well unless you've been through the parts sourcing and ordering process, you haven't:

- Had to navigate the monster parts sites like mouser.com to try and find a specific part
- Ordered the potentiometer you thought you needed and then received some bizarre 80mm reverse taper pot with a 12" shaft (or received a tube of surface mount opamps instead of the DIP ones you thought you were ordering)
- Had the excitement of breadboarding a new circuit and then realized you are out of 47nf film caps

To come up with a good list of parts, I went back through a lot of beginner and intermediate projects I have done and compiled a good cross-section of parts. There should be enough here for you to be hacking for a good long time.

This section introduces each of the component types. By the time you are done with this section you should be able to identify component types, understand their basic purposes, and de-code values. This skill alone can be invaluable as an ice-breaker with women.

Super Helpful Hint Alert

The easiest way to deal with resistor codes and capacitor codes, along with a lot of other useful stuff is to download the free Electronics Assistant program from http://electronics2000.co.uk/. It does all the conversions for you, has code calculators and a gob of other useful stuff. There is also a very usable web-based version there. Do yourself a favor, download it!

Keeping Stuff Organized

You'll notice that lots of the parts come organized in bags or boxes. As you work with projects, you'll save yourself a lot of time and trouble by staying organized. When you are done with a part, put it back in the place where it came from so you don't end up with a pile of unsorted components. For examples, resistors are a lot easier to find if they are in the bag that has the value written down ☺. Also try to keep ceramic capacitors in one bag, film capacitors in one bag, etc.

Caution: Sensitive Devices

Semiconductors are sensitive to static! This means the transistors, diodes, and integrated circuits in your kit. Keep all the parts in their respective bags/boxes until you need them. You can easily fry a component by giving it even a small does of static!

Capacitors

A capacitor is a passive device that can store power. They are commonly used as energy storage devices, but their ability to differentiate between high and low frequencies, and their use in blocking DC voltages is what makes them useful in stompboxes.

When you see a capacitor used in stompbox/audio type circuits, they are most commonly there to act as a coupling device or to form a filter.

Your kit contains a variety of capacitors. This section explains the different types and how to decode the values. (You can learn more about capacitors at the beavis website: http://www.beavisaudio.com/techpages/Caps)

Unit of Measure and Capacitor Types

Capacitance is measured in farads. 1 farad is a really huge value, so it is more convenient to parse the farad into the following units of measure: microfarads, nanofarads and picofarads.

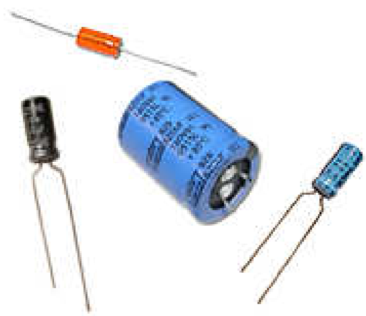
1 microfarad = 1000 nanofarads = 100000 picofarads

Electrolytics and tants are usually rated using microfarads, films are usually in nanofarads and picofarads are usually for ceramics. That's the convention I use for schematics and layouts, so in general:

- Picofarad (**pf**) capacitors will be ceramic types
- Nanofarad (**nf**) capacitors will be film types
- Microfarad (**uf**) capacitors will be electrolytic types

Electrolytic Capacitors

Electrolytic capacitors are visually distinguished by their "can" form factor. They are commonly used in power supply filtering and decoupling applications. They are polarized which means that they have a positive side and a negative side

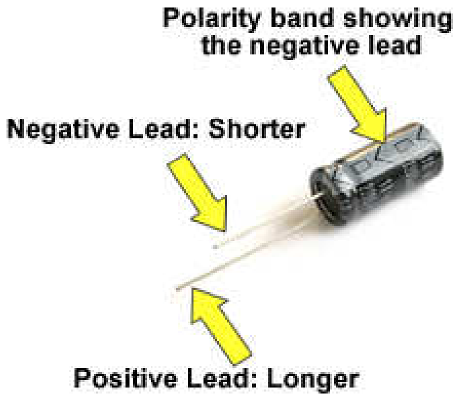


Configurations

- Axial: There are leads coming out either end of the cap. Typically mounted parallel to the board.
- Radial: Both leads come out of one end. Typically mounted vertical to the board. These are the kind supplied with the beavis board because they work well in breadboard orientations.

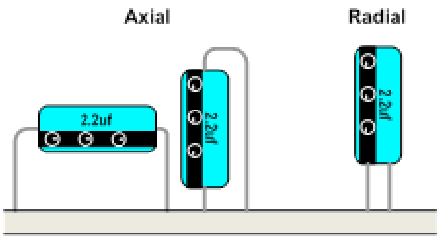
Polarity and Orientation

The polarity of the electrolytic capacitor is almost always indicated by a printed band. Additionally, the positive lead is usually longer.



Electrolytic Capacitors on the Breadboard

Your parts stash may contain a combination for radial and axial parts. Both are the same in function, but are oriented in different ways on the breadboard. As you build projects, you can choose how to orient the parts based on how the circuit is laid out.



Film Capacitors

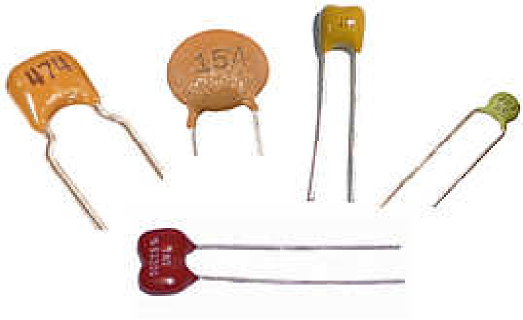
Film caps are typically available in ranges from picofarads up to 1mfd or so. They are used in decoupling stages, tone controls and sometimes in power supply filtering. Film caps also come in an almost bewildering array of compositions but you'll find polyester film, metalized polyester film, and propylene to be the most commonly available. Film caps are non-polarized, and as such, lack orientation markings.

Configurations

- Axial: There are leads coming out either end of the cap. Typically mounted parallel to the board.
- Radial: Both leads come out of one end. Typically mounted vertical to the board. These are the kind supplied with the beavis board because they work well in breadboard orientations.

Ceramic Caps

Ceramic caps are typically used for lower capacitance jobs. Values are usually in the picofarad to low nanofarad range. They are ugly looking, and that is about as technical as I'll get on the whole ceramic vs. film caps debate.



Most folks cannot discern an audible difference between the two types in common stompbox use, so you'll have to try for yourself.

A good rule of thumb is to remember that from an electrical engineering standpoint, film capacitors are generally preferred over ceramics in audio path applications unless you are going for a more vintage or "grainy" sound. Ceramics are non-polarized and usually supplied in the radial lead configuration.

Units of Measure and Codes

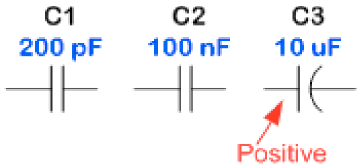
Most ceramic and film capacitors use a code to denote the value, so you'll need to decode the values according to the standard capacitor code scheme. Electrolytic capacitors are much easier—they have the actual value printed on the part (how novel!). And finally, you may come across some ceramic and film capacitors that show the actual value instead of using a code.

Here’s a table that shows values in both nanofarads (nf) and microfarads (uf) along with the codes. The yellow columns show the values in the most commonly used unit of measure for that type (i.e. ceramic capacitors are usually small values and measured in picofarads).

Value in pico farads (pf)	**Value in nanofards (nf)**	**Value in microfarads (uf)**	**Code**
Ceramic Capacitors			
10 pf	.01	n/a	100
22 pf	.022	n/a	220
30 pf	.030	n/a	300
33 pf	.030	n/a	330
47 pf	.047	n/a	470
56 pf	.056	n/a	560
82 pf	.082	n/a	820
100 pf	.1	n/a	101
220 pf	.22	n/a	221
470 pf	.47	n/a	471
Film Capacitors			
1000	1 nf	.001	102
2200	2.2 nf	.0022	222
3300	3.3 nf	.0033	332
4700	4.7 nf	.0047	472
10000	10 nf	.01	103
15000	15 nf	.015	153
22000	22 nf	.022	223
33000	33 nf	.033	333
47000	47 nf	.047	473
56000	56 nf	.056	563
68000	68 nf	.068	683
100000	100 nf	.1	104
220000	220 nf	.22	224
470000	470 nf	.47	474

Capacitors on Schematics

Capacitors appear on schematics using one of two basic symbols: parallel lines or a straight line and a curved line. In the case of parallel lines, the type is unpolarized, so for our purposes that will mean ceramic or film capacitor. When the symbol is a straight line and a curved line, the capacitor is polarized and the straight line side represents the positive side.



Resistors and Potentiometers

Resistors resist current. They come in a variety of shapes, sizes, and compounds. In stompboxes, the most commonly used part is the ¼ watt carbon film type. This is the type included in your beavis board kit. Resistors don't have polarity, so you can put either end either way. Unfortunately, resistors still are marked with the antiquated color band scheme. I still have not memorized the system after all these years, so don't feel like you have to.

Resistors

Resistors use an antiquated color band scheme. The resistors in your beavis board kit are carbon film 5% tolerance, ¼ watt types. Here is a handy table of the most common values:

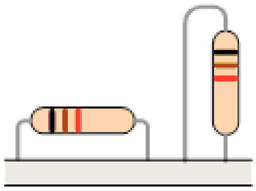
Ohms	Color	Ohms	Color	Ohms	Color	Ohms	Color
1	Brown Black Green	1.2K	Brown Red Red	12K	Brown Red Orange	120K	Brown Red Yellow
10	Brown Black Black	1.5K	Brown Green Red	15K	Brown Green Orange	150K	Brown Green Yellow
47	Yellow Violet Black	2.2K	Red Red Red	18K	Brown Gray Orange	180K	Brown Gray Yellow
100	Brown Black Brown	2.7K	Red Violet Red	22K	Red Red Orange	220K	Red Red Yellow
150	Brown Green Brown	3.3K	Orange Orange Red	33K	Orange Orange Orange	270K	Red Violet Yellow
220	Red Red Brown	3.9K	Orange White Red	39K	Orange White Orange	330K	Orange Orange Yellow
270	Red Violet Brown	4.7K	Yellow Violet Red	47K	Yellow Violet Orange	390K	Orange White Yellow
330	Orange Orange Brown	5.6K	Green Blue Red	56K	Green Blue Orange	470K	Yellow Violet Yellow
390	Orange White Brown	6.8K	Blue Gray Red	68K	Blue Gray Orange	560K	Green Blue Yellow
470	Yellow Violet Brown	8.2K	Gray Red Red	82K	Gray Red Orange	680K	Blue Gray Yellow
560	Green Blue Brown	10K	Brown Black Orange	100K	Brown Black Yellow	820K	Gray Red Yellow
680	Blue Gray Brown					1M	Brown Black Green
820	Gray Red Brown					2.2M	Red Red Green
1K	Brown Black Red					4.7M	Yellow Violet Green

Resistor Tips and Tricks

- Google resistor color codes if you want to learn and memorize them
- Your multimeter is the final word—if you are unsure of a value, check it with your meter
- You can create custom values by connecting to resistors in series. Ohms = R1 + R2

Resistors on the Breadboard

Since resistors are usually axial devices, you can insert them into the breadboard with the configuration the makes the most sense for the circuit you are working on:

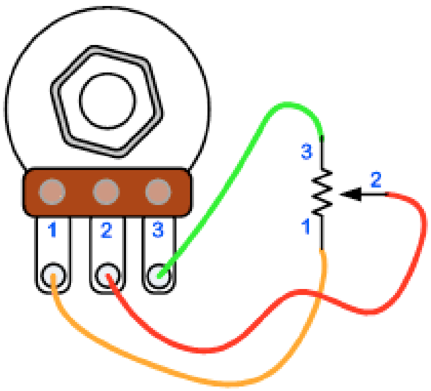


Potentiometers

Potentiometers (or pots, as we'll call them) are incredibly versatile devices. They can act as voltage dividers, or as variable resistors. There are tons of resources on the web about pots, so what I'm going to cover here are the basic types, operation, and uses specifically for guitar audio.

Lugs and Numbers

The pot has three lugs and by convention they are numbered 1,2, and 3. Pin 2 is called the wiper. These numbers map to the schematic symbol like this:



Potentiometer lug numbering with the shaft facing towards you.

Tapers

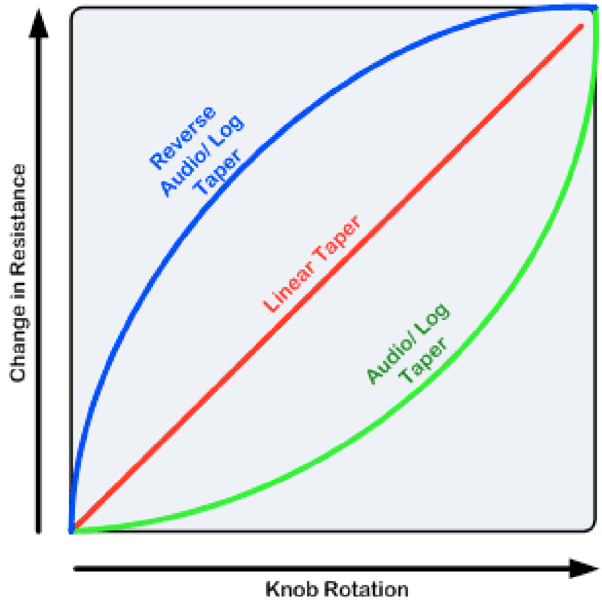
Pots come in different tapers. The taper defines how the resistance of the pot changes in relationship to turning the shaft.

- **Linear Taper:** The simplest form. The rotation of the knob directly corresponds to the resistance change in linear fashion.

- **Audio/Logarithmic Taper:** This taper compensates for how the human ear perceives changes in volume. It has a different curve—the resistance change as you turn the knob is not linear. Note that audio taper is the same thing as logarithmic (or "log" as you will sometimes see it). Just different names.

- **Reverse Audio/Log Taper:** This has the same curve as the audio taper, but in reverse.

The following diagram shows the relation of resistance change as you turn the pot knob



Which leads us to the most common first question about pots: when do I use linear and when do I use audio? The answer is, do whatever the schematic or layout you are working from specifies.

Volume controls typically use an audio taper because it is designed to change the resistance on a curve that is "smoothed out" given how our brains interpret changes in volume. Linear tapers are usually used for other parts of the circuit such as tone controls, distortion levels, etc. But not always!

The good news is that you can interchange linear and audio tapers in a pinch. If a project calls for a 100k audio taper and you only have a 100k linear taper, the linear one will work. In other words, the exact same changes in resistance will be available on audio/log and linear tapers, it just depends on where you have the knob turned to. In general, stick to the specified taper for best results. Your beavis board kit comes with various values of linear and audio/log taper pots.

Potentiometer Codes

Potentiometers have very simple codes: a Letter and a Value.

The code is

- A single letter, A for audio/log, B for linear

and

- A Numeric value, i.e. 10K

So a 100kΩ linear taper would be B100K. A 1k audio taper would be A1K. There, now you know the code. It should be noted that back in the old days the A and B were reversed—if you are working some old mystery pots, the above coding scheme may need to be reversed.

You can learn more about potentiometers here: http://www.beavisaudio.com/techpages/Pots

Trimmers

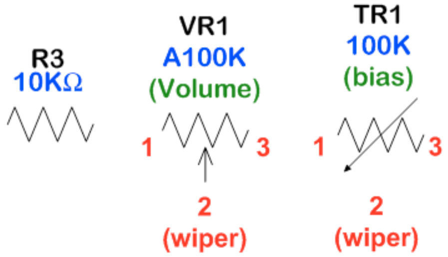
Your kit ships with some trimmers. These are "mini" pots that are used as a "set and forget" kind of thing. Most often, trimmers are soldered to the PCB and then used to tune the circuit. After that initial tune setting, they are left alone. These can work on the breadboard and are good for tight spots. Trimmers are almost always Linear Taper

Pots on the Breadboard

Your pots come pre-wired with three colored wires soldered to the lugs. When you add a pot to your breadboard circuit, be sure to look a the color for each wire and match it up against the lug number on the actual pot. The wires themselves are breadboard jumper wires so they should insert easily.

Resistors, Pots and trimmers in Schematics

Resistors are not polarized devices, they work either way. Pots and trimmers have three connections so be sure to match up the correct lug number as shown on the schematic



Trimmers

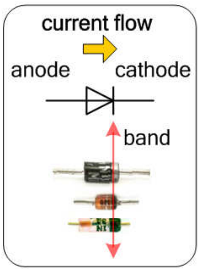
Your kit includes some trimmers. These are like mini-pots that don't have a knob. Circuit-wise, they work exactly like a linear potentiometer. For breadboard use, they are very convenient replacement for pots, especially in tight layouts. To use a trimmer, insert it in the breadboard and use a small screwdriver to adjust the value.

Diodes

A diode is a device that allows current to only flow in one direction. The two general classes of diodes are thermionic diodes, based on electron tubes, and semiconductor diodes which are usual PN junction devices.

The Diode has an anode and a cathode, current flows from the anode to the cathode, but not vice versa. Diodes are used in stompboxes for a variety of purposes. The most common is to clip (diode clipping) the audio signal to produce distortion. Diodes are also used for reverse polarity protection.

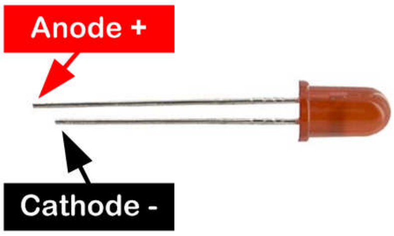
Diodes are polarity sensitive, and the cathode side is indicated by a colored band. The following graphics shows this:



For stompbox use, you are typically going to use small signal diodes. These can handle about 100mA of power.

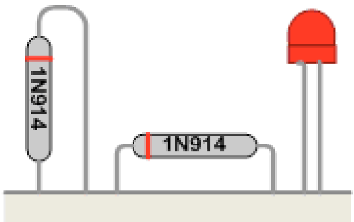
LED Orientation

Since a LED is just a special type of diode, it follows the same convention in terms of having an anode and a cathode. In terms of packaging, the longer leg is always the positive side.



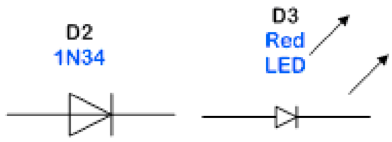
Diodes and LEDs on the Breadboard

Diodes are usually axial devices and LEDs are usually radial devices, so as with other component types, use the breadboard orientation that makes the most sense for you.



Diodes and LEDs in Schematics

Since these are polarized devices, be sure to match up the correct legs with the schematic or breadboard layout.



Helpful Hint

Diodes can be *really* hard to identify. The glass tube ones are often unreadable. For that reason, diodes are packaged in the parts stash in their own bags by type. As you are breadboarding, be sure to put the diodes back in their proper bags by type.

Transistors

Transistors are amazing devices—three little legs sticking out of a can or plastic blob. But they are powerhouses and can be used as electronic switches, or as amplifiers. Your beavis board kit has a great assortment of bipolar silicon, and FET type transistors. Each one has slightly different characteristics; the one we are usually most concerned with for stompbox use is Gain, or hFE.

Here's an overview of the types of transistors in the parts stash.

Type	Description
2N2222A	Low-gain bipolar silicon NPN
2N3904	Medium-gain bipolar silicon NPN
2N3906	Medium-gain bipolar silicon PNP
2N4401	Medium-gain bipolar silicon NPN
2N5088	Hi-gain bipolar silicon NPN
BC109	Medium-gain bipolar silicon NPN
MPSA18	Medium-gain bipolar silicon NPN
2N5457	Medium-gain N-channel FET
2N5458	Medium-gain N-channel FET
2N7000	Medium-gain N-channel FET
BS170	Medium-gain N-channel FET
J201	High-gain N-channel FET
MPF102	N-channel RF amplifier FET

Transistors almost always have three legs, and the pin outs (i.e. which leg is the Base, which is the Collector, and which is the Emitter) can be confusing. One of the most common reasons a

transistor-based circuit won't work for you is that you inserted the transistor wrong.

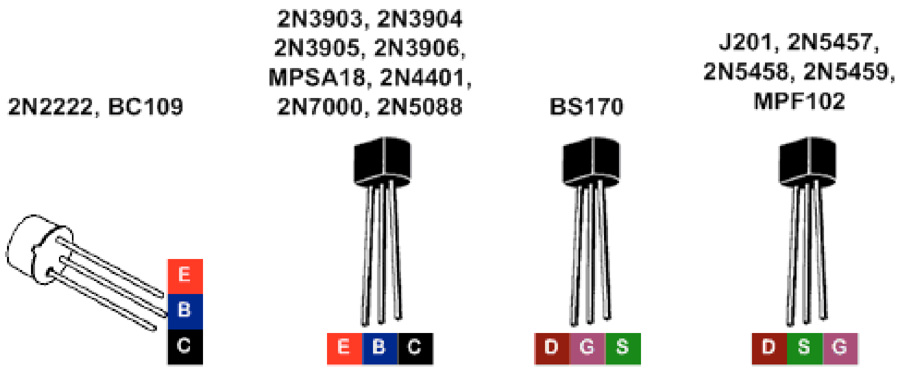
Caution: Sensitive Devices

Semiconductors are sensitive to static! This means the transistors, diodes, and integrated circuits in your kit. Keep all the parts in their respective bags/boxes until you need them. You can easily fry a component by giving it even a small does of static!

Transistor Pin outs

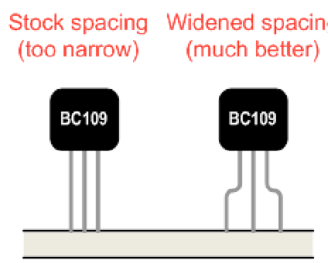
The transistor in your kit consist of a variety of bi-polar silicon, and JFET devices. Here are the pin outs for the most common values. If you ever get stuck on a pin out, just Google it. You'll find datasheets or other resources that will get you pin outs for just about any part in the world.

Super Helpful Hint Alert: A helpful fellow in Japan created a great page with pin outs: http://hamradio.lakki.iki.fi/new/Datasheets/transistor_pin outs



Transistors on the Breadboard

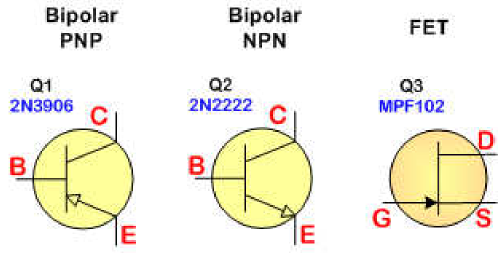
The standard pin spacing of a transistor is usually matched up to line up with three consecutive holes on the breadboard. This can be problematic when you are trying to insert a bunch of components around the transistor because they get all bunched up. Here's a great solution to that problem: bend the transistor legs a little wider so that they'll line up with every other hole. This gives you more room to work in. All the project layouts use this configuration.



Transistors on Schematics

There are three general types of transistors you'll use in stompbox/audio circuit building: Bipolar silicon and Field Effect Transistor (FET). Each has a different type of schematic symbol. Additionally, bipolar transistor can be NPN or PNP type, and FETs can be n-channel or p-channel

types. Don't worry too much about this yet, because as long as you use the right transistor value and match up the pin outs with the legs on the breadboard diagram, you'll be fine.



Integrated Circuits

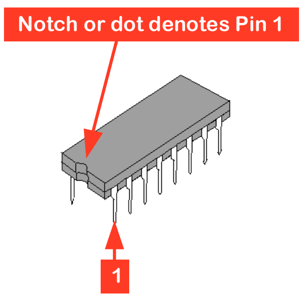
Integrated Circuits (known as 'chips' in the vernacular) are even more amazing the transistors, because inside, they contain hundreds or thousands, or even millions of transistors. ICs are roughly divided into linear and logic types. Linear types include operational amplifiers, and logic types include counters, logic gates, etc. There is a great assortment of ICs in your kit, enough to try a bunch of different circuits.

Caution: Sensitive Devices

Semiconductors are sensitive to static! This means the transistors, diodes, and integrated circuits in your kit. Keep all the parts in their respective bags/boxes until you need them. You can easily fry a component by giving it even a small does of static!

Integrated Circuit Pin Outs

The chips in your kit are plastic dual inline package (DIP) devices with a variety of pin counts and pin outs. Note that the chip orientation is always denoted by a notch, or printed dot, on one end.

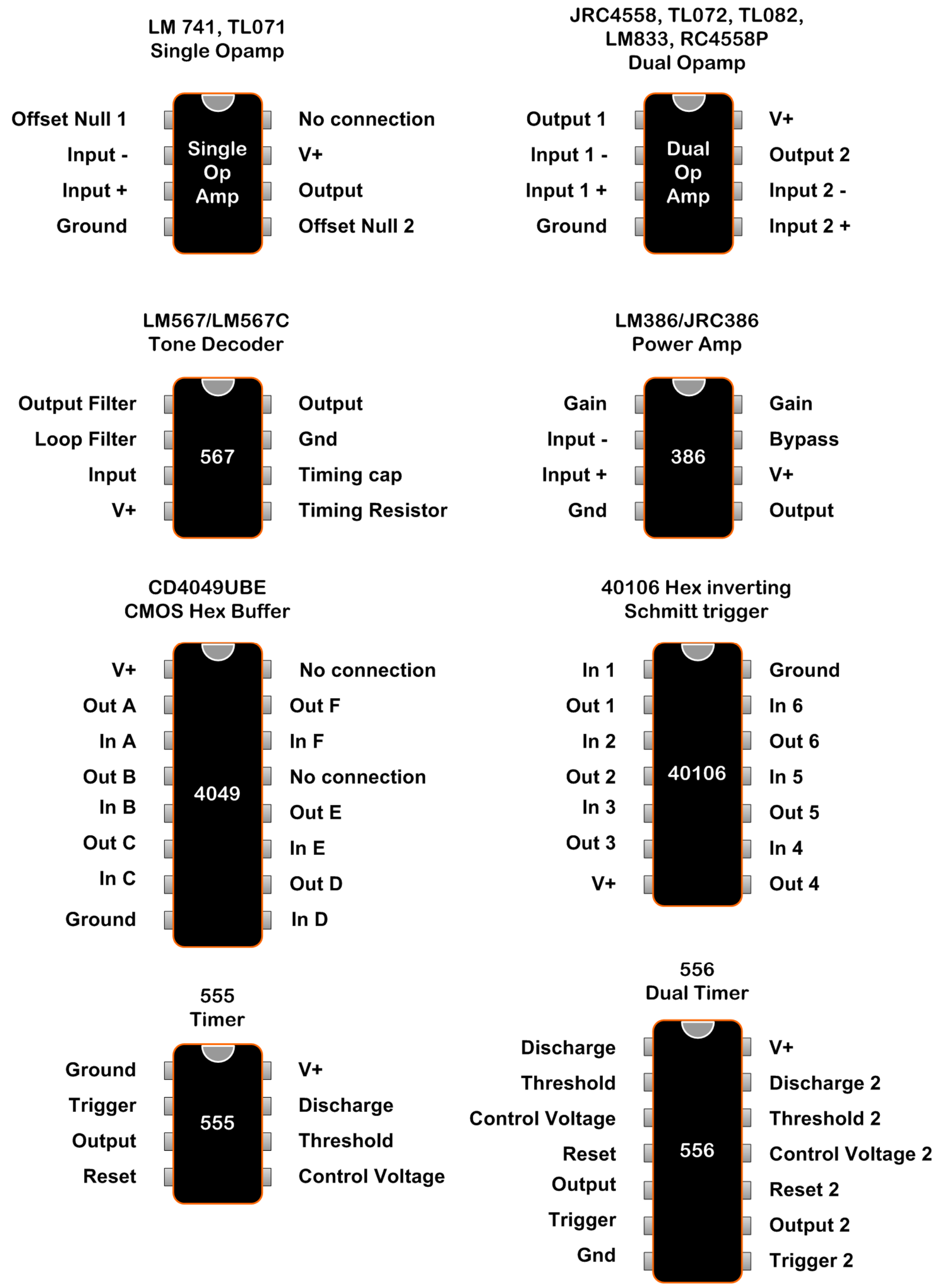


Here’s an overview of the types of integrated circuits in the parts stash.

Type	Description
LM741	Single opamp
TL071	Single opamp
JRC4558	Dual opamp
LM833	Dual opamp
NE5532	Dual opamp
RC4558P	Dual opamp
TL072	Dual opamp
LM386N3	Power amp
JRC386	Power amp
TS555CN	Timer
LM556	Dual Timer
LM567	Tone decoder
CD4049UBE	CMOS hex buffer
40106	Hex inverting Schmitt trigger

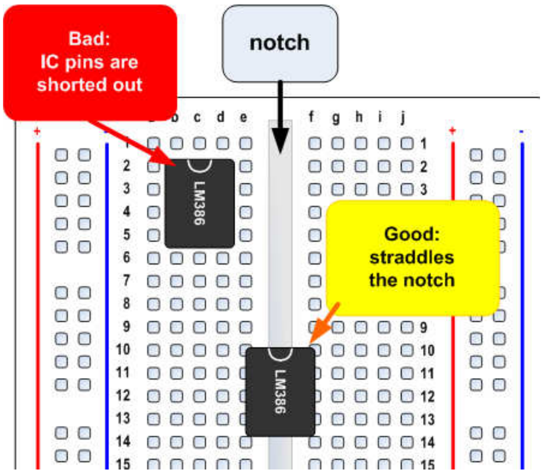
IC Pin outs

Here's a chart of pin outs:



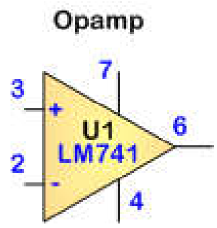
Integrated Circuits on the Breadboard

All ICs have standardized pin spacings. This means they will fit easily into a breadboard. But they have sets of pins in rows, so you can place them in a way were they would share a connected row on the breadboard. That's why most breadboards are designed to have a disconnected "notch" running down the center. Insert your IC so it straddles this notch. Also remember that you need to correctly insert your IC knowing where pin 1 is. Look for the notch on the chip and the notch shown on the breadboard diagram.



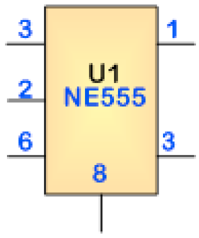
Integrated Circuits in Schematics

Because integrated circuits come in some many configurations, you'll find there are several representations for them. The most common IC used in stompbox circuits is the operational amplifier or opamp. This has a pretty standard pin out and configuration across types so it has its own schematic symbol.

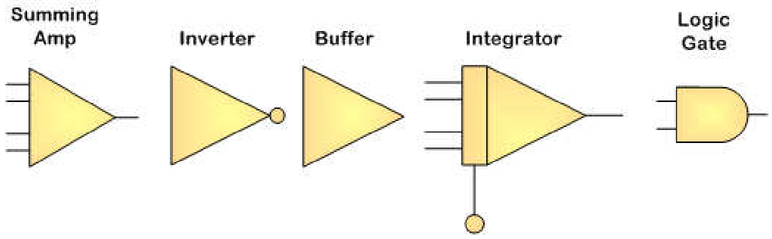


We can see that the opamp symbol is a triangle with two inputs and one output. Opamps have negative and positive inputs, so those are shown. Also shown are the pin numbers for the specific opamp.

There are many types of ICs that are specialized enough that they don't have their own specific schematic symbol, so they are drawn as a rectangle or square with pins shown in whatever order makes sense in the schematic layout:



There are also logic and other types of integrated circuits that have their own schematic symbols, like these:



Getting More: Great parts sources

While the bag o' parts in your beavis board kit is a great source, it represents about 1/100th of what is out there. As you move forward with more designs, you'll know doubt want to build up your parts stash. Here are some great online resources for getting parts:

Big Guys, bazillions of parts

www.mouser.com

www.alliedelec.com

www.digikey.com

Medium Guys, lots of parts

www.jameco.com

www.futurlec.com

www.banzaieffects.com

Stompbox/Audio Specific

www.smallbearelec.com

www.pedalpartsplus.com

www.effectsconnection.com

Great Surplus Sites

www.allelectronics.com

http://www.goldmine-elec.com

http://www.action-electronics.com

Troubleshooting

So you've followed all the steps and a circuit doesn't work.

Frustrating isn't it? Here are some things to look for as you are debugging your circuit.

1. Big picture things first. These are the really simple things that happen often enough. So look at the big things first before you get into an exhaustive post-mortem on the breadboard part.
    a. Is the power getting to the breadboard?
    b. Is your amp turned on?
    c. Did you plug your guitar into the output and your amp into the input?
    d. Is the battery dead?
    e. Is the voltage knob turned all the way clockwise to supply the necessary power to the board?
2. Orientation: This always trips us up.
    a. Transistors in the right way?
    b. ICs in the right way?
    c. Diodes? Electrolytic capacitors?
    d. They all are polarity/orientation sensitive.
3. Values: Did you use the right transistor? Right resistor values? Resistors can be especially easy to confuse because of that damn awful color coding.
4. Overall placement: Go back to the breadboard layout diagram for your project. Verify each component value and put a check mark next to it with a pencil. Then verify the connections. Loose wire? Jumper going to the wrong place?
5. Do it tomorrow. Sometimes the absolute best way to solve a problem is to go away. Your productivity in spotting an error is inversely proportional to the amount of time you spend staring at it. If you the above steps don't help and you've spent more than half an hour, take a break. Go for a walk, play your guitar, do whatever to get you away. I've solved more "hard" problems with this approach than any other.

Contact Beavis

If you are having trouble, or have ideas or successes to share, send me an email! My address is **dano@beavisaudio.com**

Please note the beavis enterprise is a weekends and evenings part-time thing for me, so it may take a while to get back to you via email.

Index

M

N

O

P

R

S

T

V

W